Environmental Pollution 242 (2018) 383–389

Contents lists available at ScienceDirect

Environmental Pollution

journal homepage: www.elsevier.com/locate/envpol

Cadmium, copper and lead levels in different cultivars of lettuce and soil from urban agriculture☆

Bruno M. Dala-Paula [a, 1], Flávia B. Custódio [a, 2], Eliana A.N. Knupp [b], Helena E.L. Palmieri [b], José Bento B. Silva [c, 3], Maria Beatriz A. Glória [a, *]

[a] LBqA - Laboratório de Bioquímica de Alimentos, Departamento de Alimentos, Faculdade de Farmácia, Universidade Federal de Minas Gerais, Av. Presidente Antônio Carlos 6627, Belo Horizonte, Minas Gerais, 31270-901, Brazil
[b] CDTN - Centro de Desenvolvimento da Tecnologia Nuclear, Cx Postal 941, 31270-901, Belo Horizonte, Brazil
[c] Laboratório de Absorção Atômica, Departamento de Química, ICEX, Universidade Federal de Minas Gerais Brazil

A R T I C L E I N F O

Article history:
Received 2 March 2018
Received in revised form
18 April 2018
Accepted 23 April 2018

Keywords:
Sustainability
Trace metals
Cadmium
Copper
Lead
Food safety

A B S T R A C T

Urban agriculture plays an important role in sustainable food supply. However, because of the atmospheric pollution and soil contamination associated with urban areas, this activity may be of concern. In fact, contamination of soil with metals and the transference of contaminants to vegetables can represent health and safety risks associated with urban agriculture. The objective of this study was to evaluate the concentrations of selected trace metals (cadmium, copper and lead) in three lettuce cultivars produced in three different urban gardens in the metropolitan region of Belo Horizonte, Brazil and their respective soils. Samples of lettuce and soil were analyzed by inductively coupled plasma mass spectrometry (ICP-MS) and graphite furnace atomic absorption spectrometry (AAS-GF), respectively, and their transfer coefficients were calculated. The methods were optimized and were fit for the purpose. Copper was the prevalent metal found in soils and lettuce, with an average of 27.9 ± 13.9 and 0.608 ± 0.157 mg kg^{-1} respectively, followed by lead (19.4 ± 7.7 and 0.037 ± 0.039 mg kg^{-1}), and cadmium (0.16 ± 0.03 and 0.009 ± 0.005 mg kg^{-1}). Cadmium presented the largest transfer coefficients, ranging from 0.34 to 1.84 with an average of 0.92 ± 0.45, which may indicate a potential risk of accumulation in vegetables in the case of high soil contamination. A significant positive correlation was observed ($p < 0.01$) between cadmium in lettuce and in soil. Even though lead concentrations varied in the soils from the different urban areas, ranging from 11.88 to 30.01 mg kg^{-1}, no significant difference ($p < 0.05$) was found among the lettuce, probably due to its low mobility (transfer coefficient = 0.02). The copper and cadmium levels found in lettuce indicate safe lettuce production in the three urban gardens.

1. Introduction

It is forecasted that the world population will reach about 9 billion inhabitants by the year of 2042, concentrated particularly in urban areas. This will create an increasing demand for food (US Census Bureau, 2011; Ondo et al., 2013). In response to this challenge, the use of urban and peri-urban areas for agriculture purpose has been considered a strategy to increase population sustainability, mainly in developing countries (Nabulo et al., 2012).

According to Brown et al. (2016), urban food production has been associated with a wide range of benefits. From a public health perspective, urban agriculture has been linked to improved nutrition, increased levels of physical activity, higher exposure to nature, and increased food security. This activity also reduces the need for transportation of food from production centers outside of the urban center, which diminishes costs. Therefore, eating food grown locally reduces transportation needs and, thus, saves energy and reduces gas emissions (Cheng et al., 2015). A special concern associated with urban agriculture is food safety. Vegetables growing in urban gardens located close to vehicle traffic and

☆ This Paper has been recommended for acceptance by Joerg Rinklebe.
* Corresponding author.
E-mail address: mbeatriz@ufmg.br (M.B.A. Glória).
[1] Present address: Curso de Nutrição, Universidade Federal de Alfenas, Rua Gabriel Monteiro da Silva, 700, Alfenas, Minas Gerais, 37130–001, Brasil.
[2] Present address: Curso de Nutrição, Universidade Federal do Rio de Janeiro campus Macaé, Rua Aloísio da Silva Gomes 50, Granja dos Cavaleiros, Macaé, Rio de Janeiro, 27930–560, Brasil.
[3] In Memoriam.

https://doi.org/10.1016/j.envpol.2018.04.101
0269-7491/

factories have an increased risk of trace metal contamination from pollutants (Ondo et al., 2013; Folens et al., 2017; Leitão et al., 2018). Atmospheric metal aerosols, fossil fuel combustion, industrial emissions, automobile exhausts, mining, as well as irrigation with untreated sewage water and sludge are considered the sources of major plant and soil pollution (Khan et al., 2016; Antoniadis et al., 2017a; Huang et al., 2018). Furthermore, trace metals can be transferred from soil to crops and could result in health hazards to consumers (Luo et al., 2012; Li et al., 2015; Khan et al., 2017). Zinc, cadmium, lead and copper are the main pollutants of urban soils (Efremova et al., 2013). The contents of these metals correlate positively with traffic volumes, as well as with road designs (Horstmeyer et al., 2016).

The intake of trace metals, whether essential or not, at high concentrations may cause reduced growth, increased mortality and may induce mutagenic effects in humans. In 2010, the Joint FAO/WHO Expert Committee on Food Additives (JECFA) changed the provisional tolerable weekly intake (PTWI) of cadmium from 7.0 $\mu g\ kg^{-1}$ body weight (bw) to a provisional tolerable monthly intake (PTMI) of 25.0 $\mu g\ kg^{-1}$ bw because it was observed that cadmium can reach a long half-life in human kidneys (FAO/WHO, 2011). In 2011, JECFA concluded that it was not possible to establish any lead PTWI levels that would be scientifically acceptable for human health (FAO/WHO, 2011). On the other hand, copper PTWI has been kept at 500 $\mu g\ kg^{-1}$ bw since 1982 (FAO/WHO, 1982).

Lettuce represents the most frequently and worldwide consumed green leaf vegetable (Cruz et al., 2014) and its consumption, along with other vegetables, may be one of the most significant sources of trace metal intake through the diet. Li et al. (2015) determined the concentration of some heavy metals (Cr, Ni, Cu, Pb and Cd) in five types of vegetables to find that lettuce leaves accumulated the highest concentrations. Thus, since high concentrations of toxic metals in vegetables are associated with adverse health effects (Huang et al., 2018), metal pollution in soils is an important environmental and toxicological concern. This might discourage urban agricultural initiatives, which have received increased attention in recent years as a way to provide fresh and low-cost food and nutrients, warranting food security to vulnerable populations. The mobility of metals in soil, together with their absorption and bioaccumulation in vegetables, is dependent on many factors including: soil pH, redox potential, soil composition, organic matter, clay content, soil cation exchange capacity, the nature and quantity of elements, aging of added elements, soil-plant interface, microbial activity in the rhizosphere, nutrient balance, climate, atmospheric depositions, metal permissibility, selectivity and the absorption ability of the species (Antoniadis et al., 2017a; dos Santos-Araujo et al., 2017; Khan et al., 2017), as well as fertilizer sources (Stellacci et al., 2013).

The presence of trace metals in urban soils and vegetables grown in urban or peri-urban areas throughout the world has been investigated in China (Wei and Yang, 2010; Huang et al., 2018), France (Ondo et al., 2013); Germany (Antoniadis et al., 2017b), India (Sharma et al., 2009; Srinivas et al., 2009), Pakistan (Abbasi et al., 2013, Khan et al., 2016, 2017), Portugal (Leitão et al., 2018), Russia (Efremova et al., 2013), Uganda (Nabulo et al., 2012). However, information on urban areas in Brazil remains scarce (França et al., 2017).

Therefore, the objective of this study was to determine the concentrations of cadmium, lead and copper in the soil and lettuce (three cultivars) produced in three different urban gardens within the metropolitan area of Belo Horizonte, Minas Gerais, Brazil, which is a region highly involved in mining activities. The transfer coefficient of the three metals from soil to lettuce leaves were also investigated.

2. Material and methods

2.1. Study area

Three lettuce cultivars were grown in three different urban gardens located in the metropolitan region of Belo Horizonte in the state of Minas Gerais, Brazil, from July to September of 2011. The average climatic conditions during the study were 21.5 ± 5.0 °C, 50.6 ± 4.2% relative humidity and 2 days of precipitation with a total volume of 1.4 mm (INMET, 2014).

Three urban gardens with different characteristics were selected: *Horta Comunitária do Cafezal* (Cafezal), *Jardim Produtivo* (Jardim), and *Centro Metropolitano de Agricultura Urbana e Familiar* (Centro) (Fig. 1.). Cafezal (latitude: −19.936047 and longitude: −43.911781) is located in the Cafezal *favela*, within the *Aglomerado da Serra favelas* in the south-central part of Belo Horizonte. The garden is situated in an elevated area with a moderate volume of vehicle traffic and is far from industrial activities. Jardim (latitude: −20.009295 and longitude: −44.006626) is located in a residential area with moderate vehicle traffic and no nearby industrial activities. Centro (latitude: −19.887798 and longitude: −44.052175) is located in an industrial area with heavy, large-sized vehicle traffic, 500 m away from two Brazilian Federal highways, BR-135 and BR-040. The three urban gardens were previously abandoned areas used by locals as trash dumps.

2.2. Sample preparation and collection

Samples of lettuce (*Lactuca sativa* L.) from three cultivars: *Baba Summer* (Baba), *Regina Summer* (Regina) and *White Paris Island Cos* (Paris) were grown from seeds of the same batch from Isla® (Porto Alegre, RS, Brazil). The lettuce plants were kept for seven weeks in a greenhouse and were transferred, on the same day, to previously prepared plots (one for each cultivar) in the three urban gardens (Cafezal, Jardim and Centro). Chemical fertilizers were not used. The watering regimen was standardized for all of them, twice daily, once in the morning and once in the evening. Approximately 60 days after sowing, the samples were collected for analysis.

Five units of each lettuce cultivar were collected from each plot to form a pool. Lettuce samples of each pool were washed individually in running deionized water, lyophilized for 48 h (Liobras L101, São Carlos, SP, Brazil), and ground in a stainless steel mill (GM200 Retsh Grindomix, Haan, Germany). Two subsamples from each pool were separated for metal analysis.

Simultaneously, three soil samples were collected (30 cm deep) at the same locations where the plants were grown, i.e., plots of each lettuce cultivar in the three urban gardens.

2.3. Reagents and standard solutions

Reagents used for standard solutions and for sample digestion were ultra pure grade, including nitric acid (69.5%, w/w) (Fluka, Buchs, Switzerland); hydrofluoric acid (40.0%, w/w) (Sigma-Aldrich, St. Louis, MO, USA) and boric acid (Merck, Darmstadt, Germany). Hydrogen peroxide 30% was analytical grade (Merck, Darmstadt, Germany). All solutions, standard solutions and dilutions, were prepared with Milli-Q ultra-pure water (resistivity of 18 MΩ cm, Millipore, Belford, MA, USA).

Argon (99.999%, ultra high purity) was used for plasma, sample nebulization, and as an auxiliary gas. Multi-element Standard 3 N9301720 pure plus (Perkin Elmer, Massachusetts, USA) solutions (10.0 $mg\ L^{-1}$) were used for preparing the calibration curves. All of the solutions and samples were prepared in 1% HNO_3 for ICP-MS.

Standard solutions of cadmium, copper and lead for soil analysis were prepared at 1.000 $mg\ L^{-1}$ in nitric acid (0.2%, v/v) (Merck,